
**Gas cylinders — Refillable seamless
steel tubes of water capacity
between 150 l and 3000 l — Design,
construction and testing**

*Bouteilles à gaz — Tubes en acier sans soudure rechargeables d'une
contenance en eau de 150 l à 3000 l — Conception, construction et essais*



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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: [Foreword — Supplementary information](#).

The committee responsible for this document is ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, *Cylinder design*.

This second edition cancels and replaces the first edition (ISO 11120:1999), which has been technically revised by the following:

- [Annex A](#) "Typical chemistry groupings for seamless steel tubes" is informative;
- nickel chromium molybdenum steel has been added in [6.1.1](#) and [Annex A](#) as Group V;
- reduction of maximum sulfur content in [6.2.2](#) from 0,020 % to 0,010 %; also the sum of sulfur and phosphorus is reduced from 0,030 % to 0,025 %;
- the modification of ultrasonic provisions for ultrasonic examination in [8.3](#) to include ultrasonic examination for wall thickness and for imperfections also on the supplied tubing;
- "Type Approval Procedure" has been introduced in [Clause 9](#);
- the provisions for design of tubes for embrittling gases have been revised.

It also incorporates ISO 11120:1999/Amd 1:2013.

Introduction

This International Standard provides a specification for the design, manufacture, inspection and testing of tubes at the time of manufacture for worldwide usage. The objective is to balance design and economic efficiency against international acceptance and universal utility.

This International Standard aims to eliminate concern about climate, duplicate inspections and restrictions currently existing because of lack of definitive International Standards. It does not reflect on the suitability of the practice of any nation or region.

This International Standard addresses the general requirements on design, construction and initial inspection and testing of pressure receptacles of the United Nations *Recommendations on the Transport of Dangerous Goods: Model Regulations*.

It is intended to be used under a variety of regulatory regimes, but it is suitable for use with the conformity assessment system for UN pressure receptacles of the above-mentioned Model Regulations.

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Gas cylinders — Refillable seamless steel tubes of water capacity between 150 l and 3000 l — Design, construction and testing

1 Scope

This International Standard specifies minimum requirements for the material, design, construction and workmanship, manufacturing processes, examinations and tests at manufacture of refillable quenched and tempered seamless steel tubes of water capacities exceeding 150 l up to and including 3 000 l for compressed and liquefied gases exposed to extreme world-wide ambient temperatures, normally between $-50\text{ }^{\circ}\text{C}$ and $+65\text{ }^{\circ}\text{C}$.

This International Standard is applicable to tubes with a maximum tensile strength, R_{ma} , of less than 1 100 MPa. These tubes can be used alone or in batteries to equip trailers or multiple element gas containers (ISO modules or skids) for the transportation and distribution of compressed gases.

This International Standard is applicable to tubes having an opening at each end.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 148-2, *Metallic materials — Charpy pendulum impact test — Part 2: Verification of testing machines*

ISO 148-3, *Metallic materials — Charpy pendulum impact test — Part 3: Preparation and characterization of Charpy V-notch test pieces for indirect verification of pendulum impact machines*

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6506-2, *Metallic materials — Brinell hardness test — Part 2: Verification and calibration of testing machines*

ISO 6506-3, *Metallic materials — Brinell hardness test — Part 3: Calibration of reference blocks*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 11114-1, *Gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1: Metallic materials*

ISO 11114-4, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 4: Test methods for selecting metallic materials resistant to hydrogen embrittlement*

ISO 13769, *Gas cylinders — Stamp marking*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

yield strength

stress value corresponding to the upper yield strength, R_{eH} , or, for steels that do not exhibit a defined yield, the 0,2 % proof strength (non-proportional extension), $R_{p0,2}$

Note 1 to entry: See ISO 6892-1.

3.2

quenching

hardening heat treatment in which a tube, which has been heated to a uniform temperature above the upper critical point, Ac_3 , of the steel, is cooled rapidly in a suitable medium

3.3

tempering

toughening heat treatment which follows quenching, in which the tube is heated to a uniform temperature below the lower critical point, Ac_1 , of the steel

3.4

tube

seamless transportable pressure receptacle of a water capacity exceeding 150 l but not more than 3 000 l

3.5

batch

quantity of up to 30 tubes of the same nominal diameter, thickness and design made successively from the same steel cast and processed in the same heat treatment equipment (i.e. a continuous furnace process or a single furnace charge, for both austenitization and tempering) using the same heat treatment parameters

3.6

test pressure

p_h

required pressure applied during a pressure test

Note 1 to entry: It is used for tube wall thickness calculation.

3.7

design stress factor

F

ratio of the equivalent wall stress at test pressure, p_h , to guaranteed minimum yield strength, R_{eg}

3.8

laminar imperfection

any imperfection lying essentially parallel to the tube surface, within the thickness of the product

3.9

working pressure

settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full tube

4 Symbols

a	Calculated minimum thickness, in millimetres, of the cylindrical shell
a'	Guaranteed minimum thickness, in millimetres, of the cylindrical shell
A	Percentage elongation after fracture
D	Nominal outside diameter of the tube, in millimetres
f	A constant in the design stress factor (see 12.3)
F	Design stress factor (variable) (see 3.7)

L_0	Original gauge length, in millimetres, according to ISO 6892-1
p_h	Hydraulic test pressure, in bar ¹⁾ , above atmospheric pressure
p_w	Working pressure, in bars, above atmospheric pressure
R_{eg}	Minimum guaranteed value of yield strength, in megapascals
R_{ea}	Actual value of the yield strength, in megapascals, as determined by the tensile test (see 10.2.2)
R_{mg}	Minimum guaranteed value of the tensile strength, in megapascals
R_{ma}	Actual value of tensile strength, in megapascals, as determined by the tensile test (see 10.2.2)
$R_{m \max}$	Maximum guaranteed value of the tensile strength, in megapascals
S_0	Original cross-sectional area of tensile test piece, in square millimetres, according to ISO 6892-1

1) 1 bar = 10^5 Pa = 10^5 N/m²

5 Inspection and testing

Evaluation of conformity shall be carried out in accordance with the applicable regulations of the countries of use.

To ensure that the tubes conform to this International Standard, they shall be subject to inspection and testing in accordance with [Clauses 9, 10 and 11](#) by an inspection body, hereafter referred to as the "Inspection Body", authorized to do so.

Equipment used for measurement, testing and examination during production shall be maintained and calibrated within a documented quality management system.

6 Materials

6.1 General requirements

6.1.1 Materials for the manufacture of tubes shall meet the requirements of [6.2](#), [6.3](#) and [6.4](#).

Steel for the fabrication of tubes shall be of nationally or internationally recognized compositions having proven reliability. Tubes shall be manufactured from carbon steel, carbon manganese steel, chromium-molybdenum steel, nickel-chromium-molybdenum steel, chromium-molybdenum-vanadium steel, or a similar alloy steel.

NOTE Steels of the types shown in [Annex A](#) have been proven to be acceptable by experience.

The steel shall be at least 95 % iron. New steel compositions, and steels for which limited experience exists in tube/cylinder service, shall be fully tested and approved by an authorized body and have been manufactured from not less than five casts of steel. The manufacturer of the finished tube shall provide a detailed specification with tolerances for the supplied tubing including

- chemical composition,
- dimensions, and
- surface quality.

6.1.2 The material used for the manufacture of tubes shall be steel, other than rimming quality, fully killed with aluminium and/or silicon.

The material shall have non-ageing properties, having a sufficient amount of nitrogen binding elements (e.g. Al $\geq$ 0,015 %).

In cases where examination of this non-ageing property is required by the customer, the criteria by which it is to be specified shall be agreed with the customer and shall be part of the order.

6.1.3 In order to prove the heat treatability of a certain tube type, it is recommended that the manufacturer of the tubing supply a certificate of mechanical properties, as a guidance to the tube manufacturer to achieve the properties required by this International Standard. This certificate is obtained carrying out a reference heat treatment, representative of the final heat treatment, on a sample of tubing.

6.1.4 The tube manufacturer shall establish means to identify the tubes with the cast of steel from which they are made.

6.1.5 Grades of steel used for tube manufacture shall be compatible with the intended gas service, e.g. corrosive gases and embrittling gases (see ISO 11114-1).

NOTE Additional requirements related to tubes for use with embrittling gases are given in [Clause 12](#).

6.2 Controls on chemical composition

6.2.1 A steel is defined by the steel-making process and by its chemical composition.

Steel-making shall be defined by reference to a given process (oxygen converter, electric arc furnace or equivalent) and to the killing method.

The chemical composition of the steel shall be defined at least by:

- the carbon, manganese and silicon contents in all cases,
- the chromium, nickel, molybdenum, vanadium or niobium contents when these are alloying elements intentionally added to the steel, and
- the maximum sulfur and phosphorus contents in all cases.

The carbon, manganese and silicon contents and, where appropriate, the chromium, nickel, molybdenum, vanadium or niobium contents shall be given, with tolerances, such that the differences between the maximum and minimum values of the cast do not exceed the ranges shown in [Table 1](#).

Table 1 — Chemical composition tolerances

Element	Maximum content (mass fraction) %	Permissible range (mass fraction) %
Carbon	<0,30	0,06
	$\geq$ 0,30	0,07
Manganese	All values	0,30
Silicon	All values	0,30
Chromium	<1,50	0,30
	$\geq$ 1,50	0,50
Nickel	All values	0,40
Molybdenum	All values	0,15

Elements not included in the declared chemical composition shall not be deliberately added. The content of such elements shall be limited to ensure that they have no detrimental effect on the properties of the finished product.

The combined content of the elements vanadium, niobium, titanium, boron and zirconium, shall not exceed 0,15 %. This requirement shall not apply to Group IV steels as per [Annex A](#).

The actual content of any element deliberately added shall be reported and their maximum content shall be representative of good steel making practice.

6.2.2 The maximum sulfur and phosphorus contents in the cast and check analyses shall not exceed 0,010 % and 0,020 %, respectively, and their sum shall not exceed 0,025 %.

6.2.3 The manufacturer of the finished tube shall obtain and make available the certificate of cast (heat) analyses of the steel supplied for the construction of the tube.

6.3 Heat treatment

6.3.1 Each tube shall be heat treated, and for each stage of treatment, i.e. quenching and tempering, the heat treatment procedure shall include a record of

- the temperature,
- the temperature holding time, and
- the cooling medium.

6.3.2 Heat treatment shall be carried out in such a way that it does not induce excessive stresses which could initiate irreversible damage in the tube.

6.3.3 The austenitization temperature prior to quenching shall be within ± 30 °C of the temperature retained for the steel type concerned, but it shall never be less than the upper critical point (A_{c3}) of the steel concerned.

6.3.4 Quenching in media other than oil or air is permissible provided that the method produces tubes free of cracks as verified by non-destructive examination.

6.3.5 The tempering temperature shall be within ± 30 °C of the temperature for guaranteeing specified mechanical properties but shall not be less than 540 °C.

6.4 Mechanical properties

The mechanical properties of the finished tube or the test ring shall be verified according to [10.2](#) and [11.3](#) and the results shall be in compliance with the design drawing.

6.5 Failure to meet test requirements

6.5.1 In this clause, test requirements cover only the tests required in [Clauses 9, 10](#) and [11](#).

6.5.2 In the event of failure to meet test requirements, retesting or reheat treatment and retesting shall be carried out as follows.

- a) If there is evidence of a fault in carrying out a test, or an error of measurement, a further test shall be performed. If the result of this test is satisfactory, the first test shall be ignored.

- b) If the test has been carried out in a satisfactory manner, the cause of test failure shall be identified.
- 1) If the tubes do not meet the required mechanical properties due to the heat treatment applied, the manufacturer may subject all the tubes of the batch to one further heat treatment or reject the corresponding tubes. If one or more tests prove even partially unsatisfactory results, all the tubes of the batch shall be rejected.
 - 2) If the failure is due to a cause other than the heat treatment applied, all tubes with imperfections shall be either rejected or repaired such that the repaired tubes pass the test(s) required for the repair. They shall then be re-instated as part of the original batch.

6.5.3 Where reheat-treatment is required, the tubes shall be re-tempered or re-quenched and tempered. A maximum of two austenitizing treatments is permitted. Whenever tubes are reheat-treated, the wall thickness can be affected by scale formation, therefore the guaranteed minimum thickness shall be checked in the finished tube.

7 Design

7.1 Calculation of cylindrical shell thickness

The guaranteed minimum thickness of the cylindrical shell, a' , shall be not less than the thickness calculated using the Lamé-von Mises formula, as follows:

$$a = \frac{D}{2} \left(1 - \sqrt{\frac{10FR_{eg} - \sqrt{3}p_h}{10FR_{eg}}} \right) \quad (1)$$

where the value of F is the lesser of $0,65/(R_{eg}/R_{mg})$ or $0,85$.

R_{eg}/R_{mg} shall not exceed $0,90$.

Additional requirements related to tubes for use with embrittling gases are given in [Clause 12](#).

NOTE 1 It is generally assumed that $p_h = 1,5p_w$ for compressed gases for tubes designed and manufactured to conform with this International Standard.

NOTE 2 For some applications such as tubes assembled in batteries to equip trailers or skids (ISO modules) or MEGCs for the transportation and distribution of gases, it is important that stresses associated with mounting the tube (e.g. bending stresses, see [Annex F](#), torsional stresses, dynamic loadings etc.) are considered by the assembly manufacturer and the tube manufacturer.

NOTE 3 In addition, during hydraulic pressure testing, tubes could be supported or lifted by their necks; therefore, it can be necessary to consider potential bending stresses. For general guidance, see [Annex F](#).

7.2 Design of tube ends

Tube ends shall be approximately hemispherical with thickness not less than the calculated minimum wall thickness, a . The dimensions of the tube end profiles shall be specified for each design, taking into consideration the stress distribution and the manufacturing process.

To permit internal visual inspection of the tube, an adequate opening shall be provided at the neck ends. The nominal diameter of the opening shall be greater than $D/12$. However, internal diameters of neck openings may be smaller provided appropriate tools are used to perform the visual inspection, i.e. bore scope, mirrors, high intensity lighting, etc.

When the tube ends are threaded, the thickness at the thread root shall be sufficient to take into account the developed stress in this part.

NOTE Stress analysis should be carried out to ensure that design limits are not exceeded.

7.3 Design drawing

A fully dimensioned drawing shall be prepared which includes the specification of the material such as heat treatment details, guaranteed mechanical properties and mass of the tube.

8 Construction and workmanship

8.1 General

The tube shall be manufactured from seamless steel tubing, typically hot rolled, extended/extruded or forged. The ends shall be hot formed using either forging or spinning methods.

Metal shall not be added in the process of closure of the end.

Defects shall not be repaired by welding.

8.2 Surface imperfections

The internal and external surfaces of the finished tube shall be free from imperfections which could adversely affect the safe working of the tube.

NOTE See [Annex C](#) for examples of imperfections and guidance on their evaluation.

The machined surfaces of the neck shall be inspected with a non-destructive examination method acceptable to the Inspection Body, such as magnetic particle inspection (see ISO 10893-5), dye penetrant methods (see ISO 10893-4), eddy current (see ISO 10893-2), etc., to ensure that they are free from imperfections.

8.3 Ultrasonic examination

After completion of the final heat treatment and any operation resulting in loss of wall thickness (e.g. grinding or machining), each tube shall be ultrasonically examined for internal and external defects and laminar imperfections and to determine wall thickness in accordance with [Annex B](#).

An ultrasonic examination for imperfections and wall thickness, in accordance with [Annex B](#), shall also be carried out on the supplied tubing.

The wall thickness at any point shall be not less than the guaranteed minimum thickness.

8.4 End closure (fitting)

Closure of the finished tube shall be accomplished by a method other than welding, brazing or braze welding, and shall prevent leakage.

8.5 Dimensional tolerances

8.5.1 Out-of-roundness

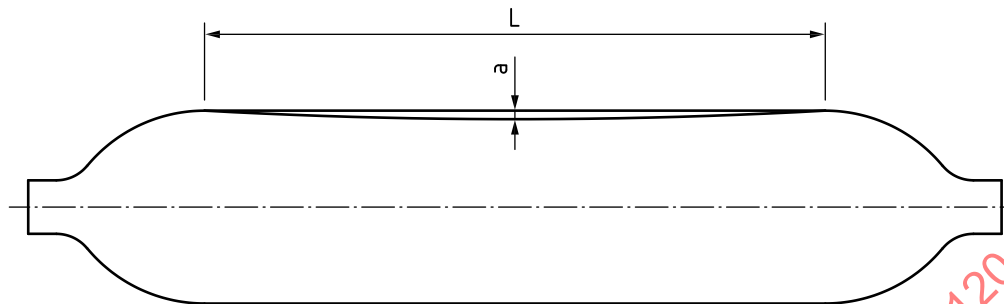
The out-of-roundness of the cylindrical shell, i.e. the difference between the maximum and minimum outside diameters at the same cross-section, shall not exceed 2 % of the mean value of these diameters measured at least at the quarter and mid-length locations on the tube.

8.5.2 Outside diameter

The mean outside diameter shall not deviate by more than ± 1 % from the nominal outside diameter; this shall be verified at the quarter and mid-length locations on the tube.

8.5.3 Straightness

The maximum deviation of the cylindrical part of the shell from a straight line parallel to the tube axis shall not exceed 0,003 times the full body length, with the exception of stand-alone applications (where tubes are not in close proximity to each other) where this value may be exceeded with written agreement of the involved parties (customer, manufacturer and Inspection Body). See [Figure 1](#).



Key

- a maximum deviation $0,003 \cdot L$
- L full parallel body length

Figure 1 — Illustration of deviation from a straight line

8.5.4 Eccentricity

The values of the minimum and maximum thicknesses shall not differ by more than 12,5 % from the mean value of these two thicknesses; this shall be verified at least at the quarter and mid-length locations on the tubes.

8.5.5 Length

The tolerance on the design overall length of the tube only, excluding fittings, shall not exceed the lesser of $\pm 1,5$ % or ± 50 mm, except that, for large tubes, $> 2\ 000$ l, these values can be exceeded with written agreement of the involved parties (customer, manufacturer and Inspection Body).

8.5.6 Water capacity

The tolerance on the design water capacity shall be within the range of $^{+10}_0$ %.

For compressed gases, with written agreement of the involved parties (customer, manufacturer and Inspection Body), a tolerance of ± 5 % may be used.

NOTE These tolerances do not relate to or affect the accuracy required for the stamp marking of the actual volume of the tube.

8.5.7 Mass

The tolerance on design mass of any individual tube shall not exceed ± 10 %. If tubes are intended to constitute a battery, the tolerance on the shipment average tube mass shall be within the range of -10 % to $+5$ % of the unit design mass.

9 Type approval procedure

9.1 General requirements

A technical specification of each new design of tube, or tube family (Design Type Specification) as defined below, including design drawing, design calculations, steel details, manufacturing process and heat treatment details, shall be submitted by the manufacturer to the Inspection Body. The type approval tests detailed in 9.2 shall be carried out on each new design under the supervision of the Inspection Body.

A tube shall be considered to be of a new design, compared with an existing approved design, when any of the following apply:

- it is manufactured in a different factory;
- it is manufactured by a different process (see 8.1); this includes the case when major process changes are made during the production period, e.g. end forging to spinning, change in type of heat treatment (including different furnace), etc.;
- it is manufactured from a steel of different specified chemical composition range as specified in 6.2.1;
- it is given a different heat treatment beyond the limits specified in 6.3;
- the overall length of the tube has increased by more than 50 % (tubes with a length/diameter ratio less than 3 shall not be used as reference tubes for any new design with this ratio greater than 3);
- the nominal outside diameter has changed;
- the guaranteed minimum thickness has changed;
- the hydraulic test pressure, p_h , has been increased (where a tube is to be used for lower-pressure duty than that for which design approval has been given, it shall not be deemed to be a new design);
- the guaranteed minimum yield strength, R_{eg} , and/or the guaranteed minimum tensile strength, R_{mg} , have changed.

9.2 Prototype tests

9.2.1 A minimum of nine tubes, which are guaranteed by the manufacturer to be representative of the new design, shall be made available for prototype testing. However, if for special applications the total number of tubes required is less than nine, a sufficient number of tubes shall be made available to complete the prototype tests required, but in this case the approval validity shall be limited to this particular production batch.

9.2.2 In the course of the type approval process, the Inspection Body shall select the necessary tubes and sample rings for testing and verify that the following is taken into account:

- the design conforms to the requirements of Clause 7 and 12.3, as appropriate;
- the thicknesses of the walls and ends on one representative tube conform to 7.1 or 12.3, as applicable, and 7.2. The measurements along the length of the cylindrical part of the tube shall be at least at one metre intervals and 90° apart around the circumference at each section. A minimum of three sections shall be tested for short tubes. Each of the ends shall be measured to ensure minimum design wall thickness at four points. In addition, areas where any machining has taken place or any other defects may be visually seen shall be measured;
- the requirements of Clause 6 are met;
- the requirements of 8.5 are met for all tubes selected;

- the internal and external surfaces of the tubes are free of any defect which might make them unsafe to use (for examples see [Annex C](#));
- the conversion of hardness test results into tensile strength values, as specified in [11.3](#), has been performed and that minimum and maximum hardness values have been established;

9.3 Type approval test report

A test report shall be drawn up, describing the results of examinations and tests carried out in accordance with [9.2](#). A copy of the test report shall be available to the Inspection Body issuing the type approval certificate.

Additional documents may be required in accordance with the relevant local regulation.

9.4 Type approval certificate

If the results of the checks according to [9.2](#) are satisfactory, the Inspection Body shall issue a type approval certificate, a typical example of which is given in [Annex E](#).

10 Batch tests

10.1 General requirements

All tests for checking the quality of tubes shall be carried out at the completion of tube manufacture, i.e. at any stage after the heat treatment.

For the purposes of batch testing, the manufacturer shall make available to the Inspection Body the following:

- the type approval certificate;
- the certificates stating the cast analysis of the steel supplied for the manufacture of the tube;
- evidence that appropriate heat treatment has been performed;
- a list of the tubes, stating serial numbers and stamp markings, as required.

The following tests and inspections shall be carried out under the responsibility of the Inspection Body (see [Clause 5](#)):

- a) one tensile test according to [10.2.2](#) and, for embrittling gas use, [12.5.1](#);
- b) one impact test according to [10.2.3](#) and, for embrittling gas use, [12.5.1](#);
- c) all the tests and inspections as per [Clause 11](#) (tests on every tube).

10.2 Mechanical tests

10.2.1 General requirements

From each production batch, test pieces shall be selected for mechanical testing from a ring of material of minimum length 200 mm taken from supplied tubing which is representative of the final condition of the tube(s), including any heat treatment. Each test ring shall be of the same nominal diameter, thickness, and material cast as the finished tubes it represents. The sample as defined above shall be placed so it is subjected at the same time as the tube(s) to the same heat treatment conditions, including with respect to single or double-sided quenching.

10.2.2 Tensile test

The test shall be carried out in accordance with ISO 6892-1 on a cylindrical proportional test piece taken longitudinally (along the axis of the ring) in the ring wall and machined. The gauge length of the test piece, L_0 , shall be $L_0 = 5,65 \sqrt{S_0}$.

The results of the tensile test shall be at least equal to the minimum guaranteed values of the properties, and in all cases

- R_{ma} shall be less than 1 100 MPa,
- the elongation after fracture, A , shall be not less than 14 %, and
- the ratio R_{ea}/R_{ma} shall be not more than 0,95.

Additional requirements related to tubes for use with embrittling gases are given in [Clause 12](#).

10.2.3 Impact testing

10.2.3.1 Except for the requirements given below, the test shall be carried out in accordance with ISO 148-1, ISO 148-2 and ISO 148-3.

The test shall be carried out on three test pieces taken longitudinally from the sample ring wall. The notch shall be perpendicular to the face of the sample ring wall. The test pieces shall be machined on all six faces. If the wall thickness does not permit a final test piece width of 10 mm, the width shall be as near as practicable to the nominal thickness of the tube wall. If the wall thickness is greater than 10 mm, the test pieces shall be taken as near as practicable to the inner surface of the sample ring and their thickness limited to 10 mm.

10.2.3.2 The impact test shall be conducted at a temperature of $-20\text{ }^{\circ}\text{C}$ and the impact test values shall meet the following requirements:

- individual values $\geq 40\text{ J/cm}^2$;
- mean value $\geq 50\text{ J/cm}^2$.

NOTE It can be demonstrated from material standards (e.g. ISO 21028-2) that a successful impact test carried out at $-20\text{ }^{\circ}\text{C}$ provides absence of risk of in-service brittle failure of a tube down to lower service temperatures (e.g. $-50\text{ }^{\circ}\text{C}$) for tube types used for transport of gases.

If agreed between the manufacturer and purchaser, impact tests at lower temperatures may be carried out according to the condition of use, provided that the foregoing test requirements are also met.

10.3 Interpretation of results

Except as given in [6.5](#), the finished tubes shall meet the requirements of [Clauses 6](#) and [11](#).

11 Tests on every tube

11.1 General

Following heat treatment, all tubes shall be subjected to the following tests and inspections under the responsibility of the Inspection Body:

- a hydraulic proof pressure test in accordance with [11.2.1](#) or a volumetric expansion test in accordance with [11.2.2](#). Test method requirements are given below. Additional guidance for these test methods and equipment control (calibration and maintenance) can be found in ISO 6406;
- a hardness test in accordance with [11.3](#);

- a visual inspection in accordance with 11.4;
- a visual check of the stamp markings;
- a dimensional inspection in accordance with 11.5;
- ultrasonic non-destructive testing (NDT) in accordance with 11.6.

11.2 Hydraulic test

11.2.1 Proof pressure test

The hydraulic pressure in the tube shall be increased at a controlled rate until the test pressure, p_h , is reached with a measuring tolerance of $^{+3}_0$ % or +10 bar, whichever is the lower.

NOTE The test is normally carried out using water.

All necessary precautions shall be taken to guarantee the safety of persons and property. The tube test pressure shall be held for a sufficiently long period (at least 2 min) to ascertain that there is no tendency for the pressure to decrease or for permanent visible deformation and that the tube does not leak.

The test mounting shall be designed and arranged to permit easy checking of the tube tightness. It shall be fitted with calibrated pressure gauge(s). Any internal pressure applied to the tube after heat treatment and before the official pressure test shall not exceed 90 % of the test pressure, p_h .

After testing, the interior of the tube shall be dried to avoid oxidation and/or corrosion.

11.2.2 Volumetric expansion test

The hydraulic pressure in the tube shall be increased at a controlled rate until the test pressure, p_h , is reached with a measuring tolerance of $^{+3}_0$ % or +10 bar, whichever is the lower.

NOTE The test is normally carried out using water.

The tube test pressure shall be held for a sufficiently long period to ensure complete expansion of the tube, but in no case shall the pressure be held for less than 2 min. The total volumetric expansion shall be measured. The pressure shall then be released and the volumetric expansion re-measured.

The tube shall be rejected if it shows permanent expansion (i.e. volumetric expansion after the pressure has been released) in excess of 10 % of the total volumetric expansion measured at the test pressure, p_h .

The total and permanent expansion readings shall be recorded, together with the corresponding serial number of the tube tested, so that the elastic expansion (i.e. total expansion minus permanent expansion) can be established for each tube.

The test apparatus shall be fitted with at least two calibrated pressure gauges arranged in a parallel configuration to check the accuracy of the pressure applied to the tube. Any internal pressure applied to the tube after heat treatment and before the official pressure test shall not exceed 90 % of the test pressure, p_h .

After testing, the interior of the tube shall be dried to avoid oxidation and/or corrosion.

11.3 Hardness testing

The purpose of the hardness test is to check the homogeneity of a tube and the level of its mechanical properties after heat treatment.

A Brinell hardness test shall be carried out on each tube in accordance with ISO 6506-1, ISO 6506-2 and ISO 6506-3, preferably with a ball having a diameter of 10 mm and at a 29 420 N (3 000 kgf) load, except when circumstances do not permit.

The conversion of hardness test results into tensile strength values shall be determined by the tube manufacturer, using test pieces representative of the manufactured tubes.

Hardness shall be measured and recorded at four diametrically opposed points in at least three circular cross-sections distributed over the whole length of each tube at intervals not greater than 3 m.

The results on each circular cross-section shall be within the minimum–maximum tensile strength range guaranteed by the manufacturer. The values may be plotted on a diagram to identify their position.

NOTE The hardness value on a single location can be the result of the average of a maximum of three tests.

11.4 Visual inspection

The inner and outer surfaces of each finished tube shall be inspected visually for cleanliness and imperfections in accordance with [8.2](#). This is intended to check, in particular for the inner surface, that

- no foreign matter or grease is present,
- no liquid or moisture is present inside the tube, and
- no shoulder cracks are present.

Light, tightly adhering scale or blush rust oxide is acceptable unless expressly prohibited by the final application.

11.5 Dimensional inspection

11.5.1 Thickness

Inspection of wall thickness to check conformity with the requirements of [8.3](#) and [8.5.4](#) shall be carried out on each tube. The inspection for eccentricity per [8.5.4](#) may be carried out at any manufacturing stage chosen by the manufacturer. However, the manufacturer shall ensure that the minimum wall thickness is not affected after this stage

11.5.2 Diameter and length

Checks of the outside diameter and length shall be carried out on each finished tube to check conformity with [8.5.1](#) to [8.5.3](#) and [8.5.5](#).

11.5.3 Water capacity and mass

The water capacity and mass shall be checked on each tube for conformity with [8.5.6](#) and [8.5.7](#).

11.5.4 Neck threads and openings

Openings and neck threads, when they are present, shall be checked using gauges corresponding to the specified dimensions, or by an alternative method agreed between the parties.

NOTE Neck threads can be internal, external or both.

11.6 Ultrasonic non-destructive test

Each tube shall undergo ultrasonic examination (UE) for imperfections and thickness verification, as specified in [8.3](#), in accordance with [Annex B](#).

12 Special requirements for tubes for embrittling gases

12.1 General

Tubes intended for the transport of gases which have a risk of hydrogen embrittlement, in accordance with ISO 11114-1, shall meet the requirements of [12.2](#) to [12.5](#), in addition to those given in [Clauses 6](#) to [11](#).

NOTE ISO 11114-1, Table 1, No. 67, Methane, states that specific compatibility requirements for natural gas are included in ISO 11439. Clause 4.5 of ISO 11439 specifies the permissible composition of natural gas and clause 7.5.2.2 specifies that during prototype testing the sulphide stress cracking resistance test describes in Clause A.3 is to be carried out when the upper limit of the specified tensile strength for the steel exceeds 950 Mpa.

12.2 Materials

The suitability for use in the production of tubes intended to contain embrittling gases and made of steels of given chemical compositions and heat treatments shall be checked. The steels shall meet the requirements of [Clause 6](#) and the additional requirements of [12.5](#); specifically, in no case shall R_{ma} exceed the values required in [12.3](#) and [12.5.1](#).

12.3 Design

The calculation of the wall thickness of the pressure containing parts shall be related to the guaranteed minimum yield strength, R_{eg} , of the material of the finished tube, using the Lamé-von Mises formula in accordance with [7.1](#), except that

$$F = \frac{f}{R_{eg}/R_{mg}} \quad (2)$$

where

$$f = 0,65 \text{ for } R_{m \max} \leq 890 \text{ MPa}$$

$$f = 0,61 \text{ for } R_{m \max} > 890 \text{ MPa}$$

$$R_{eg}/R_{mg} \text{ shall not exceed } 0,85.$$

In addition, $R_{m \max} - R_{mg} \geq 100 \text{ MPa}$.

The value of f shall be fixed at the time of designing the tube and shall not be established or changed retrospectively when the tube has been heat treated and qualified by physical testing. The value of f shall be defined according to guaranteed maximum tensile strength, $R_{m \max}$, as above.

12.4 Construction and workmanship

12.4.1 General

Special attention shall be given to the tube shoulders to ensure that their particular shape does not induce high stresses. The design of openings and of adaptors, including gaskets, shall permit variations in the tube dimensions (e.g. its volume) during filling. The internal thread and the transition area shall be manufactured with special care to avoid stress concentrations.

12.4.2 Surface imperfections

12.4.2.1 The inner and outer surfaces of each blank of supplied tubing shall be subjected to careful inspection prior to end closing-in by forging or spinning. In particular, the inner surfaces and edges of the blanks shall be free from any defect which exceeds the specified acceptance/rejection criteria. Surface inspection shall be conducted using ultrasonic non-destructive examination in accordance with [Annex B](#).

12.4.2.2 After forging or spinning of the tube ends, the internal surface of the neck and shoulder shall be examined for folds and cracks by means of an endoscope, introscope, dentist's mirror or other suitable appliance. The surface shall be free from cracks. Folds that are clearly visible as depressions having rounded peaks and roots shall not be deemed to constitute defects, but those which have sharp profiles, or whose shape cannot definitely be identified, particularly those that are only discernible as a crack or a line of oxide on the tube surface and extend into the threaded portion, are not acceptable and shall be removed.

12.4.2.3 All surface imperfections revealed by these examinations shall be removed by machining, grinding or any appropriate procedure except welding. Great care shall be taken to avoid introducing new injurious defects such as striations. After such a repair, the wall thickness shall be re-checked for conformity with [12.3](#).

12.5 Mechanical tests

12.5.1 Tensile and impact tests

Tubes shall be fully tempered to meet the following requirements.

- a) The results of the tensile test in [10.2.2](#) shall be as follows:
 - R_{ma} shall not exceed: 890 MPa if $f = 0,65$ or 950 MPa if $f = 0,61$;
 - elongation after fracture shall be not less than 16 %;
 - ratio R_{ea}/R_{ma} shall not exceed 0,90.

Values of R_{ma} higher than 950 MPa, elongation values of less than 16 % and ratio R_{ea}/R_{ma} higher than 0,90 may be used, provided the steel at this strength level is qualified in accordance with the requirements of ISO 11114-4. However, it shall be ensured that all the requirements given in [10.2.2](#) are fulfilled.

- b) For the impact test in [10.2.3](#) at the test temperature, each test piece shall exhibit a lateral expansion greater than 0,4 mm, and the fracture surface shall have a generally ductile appearance at visual inspection, i.e. the crystalline appearance of the fracture surface shall not exceed 50 %.

12.5.2 Hardness test

The purpose of the hardness test is to check the homogeneity of a tube and the level of its mechanical properties after heat treatment.

The test shall be carried out in accordance with [11.3](#).

The following requirements shall be met:

- the results of hardness readings on one circumference of the outer wall do not differ by more than 30 HB;
- at any point of the tube surface, the steel tensile strength, as calculated from a conversion of Brinell hardness values, is not greater than the maximum guaranteed value of the tensile strength specified in [12.5.1](#).

13 Inspection certificate

Each batch of tubes shall be covered by a certificate signed by the Inspection Body's representative to the effect that the tubes meet the requirements of this International Standard in all respects. [Annex D](#) provides a typical example of a suitably worded acceptance certificate. Other formats with at least the same content are also acceptable.

Copies of the certificate shall be issued to the manufacturer. The original certificate shall be retained by the Inspection Body and the copies by the manufacturer in accordance with the regulations of the relevant statutory authority.

NOTE Attention is drawn to national regulations which might have additional or overriding requirements concerning the issuing and retention of certificates.

14 Marking

Each tube shall be permanently marked on the shoulder.

Marking shall be in accordance with the applicable regulations of the countries of use.

In the absence of such regulations marking shall be in accordance with ISO 13769.

NOTE ISO 13769 should be used in all cases as a guide e.g. to cover marking requirements not specified by regulations

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Annex A

(informative)

Typical chemistry groupings for seamless steel tubes

Values in percent [mass fraction]					
Element	Group I	Group II	Group III	Group IV	Group V
C	0,32/0,48	0,25/0,40	0,35/0,50	0,15/0,50	0,27/0,35
Mn	0,90/1,65	0,40/1,00	0,60/1,05	0,40/0,70	0,50/0,70
P	≤0,020	≤0,020	≤0,020	≤0,020	≤0,020
S	≤0,010	≤0,010	≤0,010	≤0,010	≤0,010
Si	0,10/0,50	0,10/0,45	0,15/0,40	0,10/0,40	0,10/0,35
Ni	≤0,40 ^a	—	—	0,15/0,40	2,30/2,80
Cr	≤0,40 ^a	0,80/1,20	0,85/1,20	2,25/2,75	0,50/0,80
Mo	≤0,10 ^a	0,15/0,35	0,15/0,30	0,15/0,60	0,40/0,70
V	—	—	—	0,15/0,30 ^b	—
^a Ni + Cr + Mo = 0,63 max. ^b V optional.					

NOTE Usually, the materials listed in this annex do not exhibit a defined yield during a tensile test, therefore the definition of $R_{p0,2}$ applies (see 3.1).

Annex B **(normative)**

Ultrasonic examination

B.1 Introduction

This annex is based on techniques used by tube manufacturers. Other techniques of ultrasonic examination may be used, provided that these have been demonstrated to be suitable for the manufacturing method.

B.2 General requirements

The ultrasonic examination equipment shall be capable of at least detecting the reference standard notches as described in [B.3.2](#). It shall be serviced regularly in accordance with the manufacturer's operating instructions to ensure that its accuracy is maintained. Inspection records and approval certificates for the equipment shall be maintained.

The operation of the ultrasonic examination equipment shall be by qualified and experienced personnel certified at least to level 1 and supervised by personnel certified at least to level 2 of ISO 9712. Other standards which meet or exceed these minimum requirements may be used subject to approval by the Inspection Body. The inner and outer surfaces of any tube which is to be examined ultrasonically shall be in a condition suitable for an accurate and reproducible examination.

For flaw detection the pulse echo system shall be used. For thickness measurement either the resonance method or the pulse echo system shall be used. For the detection of laminar imperfections the pulse echo technique shall be used, with ultrasound transmitted in the direction normal to the tube surface. Either contact or immersion techniques of examination shall be used.

A coupling method which ensures adequate transmission of ultrasonic energy between the testing probe and the tube shall be used.

B.3 Flaw detection of the cylindrical part

B.3.1 Procedure

The tubes to be examined and the search unit shall have a rotating motion and translation relative to one another such that a helical scan of the tube will be described. The velocity of rotation and translation shall be constant within $\pm 10\%$. The pitch of the helix shall be less than the width covered by the probe (at least a 10 % overlapping shall be guaranteed) and be related to the effective beam width such as to ensure 100 % coverage at the velocity of rotation and translation used during the calibration procedure.

An alternative scanning method may be used for transverse defect detection, in which the scanning or relative movement of the probes and the work piece is longitudinal, the sweeping motion being such as to ensure a 100 % surface coverage with 10 % overlapping of the sweeps.

The tube wall shall be examined for longitudinal imperfections with the ultrasonic energy transmitted in both circumferential directions and for transverse imperfections in both longitudinal directions.

When optional examination is carried out on the transition areas between the wall and neck, this may be conducted manually if not carried out automatically.

The effectiveness of the equipment shall be periodically checked by passing a reference standard through the examination procedure. This check shall be carried out at least at the beginning and end of each shift. If

during this check the presence of the appropriate reference notch is not detected, then all tubes examined subsequent to the last acceptable check shall be re-examined once the equipment has been reset.

B.3.2 Reference standard

A reference standard of convenient length shall be prepared from tubing of similar diameter and wall thickness range, of material with the same acoustic characteristics and surface finish as the tube to be examined. The reference standard shall be free from discontinuities which may interfere with the detection of the reference notches and the rectangular recess.

Reference notches, both longitudinal and transverse, and a rectangular recess shall be machined on the outer and inner surface of the standard. The notches and the recess shall be separated such that each of them can be clearly identified.

Dimensions and shape of notches and recess are of crucial importance for the adjustment of the equipment (see [Figure B.1](#), [Figure B.2](#) and [Figure B.3](#)).

The length of the notches, E , shall not be greater than 50 mm.

The width, W , shall be not greater than twice the nominal depth, T . However, where this condition cannot be met a maximum width of 1 mm is acceptable.

The depth of the notches, T , shall be $(5 \pm 0,75) \%$ of the guaranteed minimum wall thickness, a' , with a minimum of 0,3 mm and a maximum of 1,0 mm over the full length of the notch. Runouts at each end are permissible.

The notch shall be sharp edged at its intersection with the surface of the cylinder wall. The cross-section of the notch shall be rectangular except where spark erosion machining methods are employed; then it is acknowledged that the bottom of the notch will be rounded.

The shape and dimensions of the notch shall be demonstrated by an appropriate method.

The width of the rectangular recess, b , shall be $6 \text{ mm } {}^{+10}_0 \%$.

The length of the rectangular recess, l , shall be 17 mm or less.

The depth of the rectangular recess, h , shall be between $1/4$ and $1/2$ of the guaranteed minimum wall thickness, a' , with a maximum of 10 mm.

B.3.3 Calibration of equipment

Using the reference standard described in [B.3.2](#), the equipment shall be adjusted to produce clearly identifiable indications from inner and outer surface notches and the rectangular recess. The amplitude of the indications shall be as near equal as possible. The indication of smallest amplitude shall be used as the rejection level and for setting visual, audible, recording or sorting devices. The equipment shall be calibrated with the reference standard or probe, or both, moving in the same manner, in the same direction and at the same speed as will be used during the examination of the tube. All visual, audible, recording or sorting devices shall operate satisfactorily at the test speed.

B.4 Wall thickness measurement

If the measurement of the wall thickness is not carried out in another stage of production, the cylindrical part shall be 100 % examined to ensure that the thickness is not less than the guaranteed minimum value.

B.5 Interpretation of results

B.5.1 Surface imperfections

Tubes with indications which are equal to, or greater than, the lowest of the indications from the reference notches shall be withdrawn. This comparison shall be made between the indications from the tube and those from the reference notch in the same orientation and on the same face, e.g. a transverse inside defect shall be compared with the transverse inside reference notch. The cause of the indication shall be identified and, if possible, removed; after removal the tubes shall be re-subjected to ultrasonic flaw detection and thickness measurement, conducted either automatically or manually.

B.5.2 Laminar imperfections

Any tube producing a trigger/alarm condition shall be designated suspect.

For suspect tubes, each suspect area shall be explored by a manual ultrasonic straight beam method, or by a suitable automatic or semi-automatic system, to establish the extent of the laminated suspect area. The tube shall be deemed to have passed this test if the lamination size, $B_{\max}$, is not exceeded, where

$$B_{\max} = 165 \text{ mm}^2$$

NOTE For guidance see ISO 10893-8.

B.5.3 Manual retest

Where a manual re-test is conducted, the hand scanning equipment shall be calibrated using a calibration standard as described in [B.3.2](#). The tube surfaces shall be tested for longitudinal defects with the ultrasonic energy transmitted in both circumferential directions and, for transverse defects, in both longitudinal directions. To ensure complete coverage of the reconditioned area, the manual scan shall overlap at least 15 %, and the scan shall not exceed a rate of 150 mm·s⁻¹.

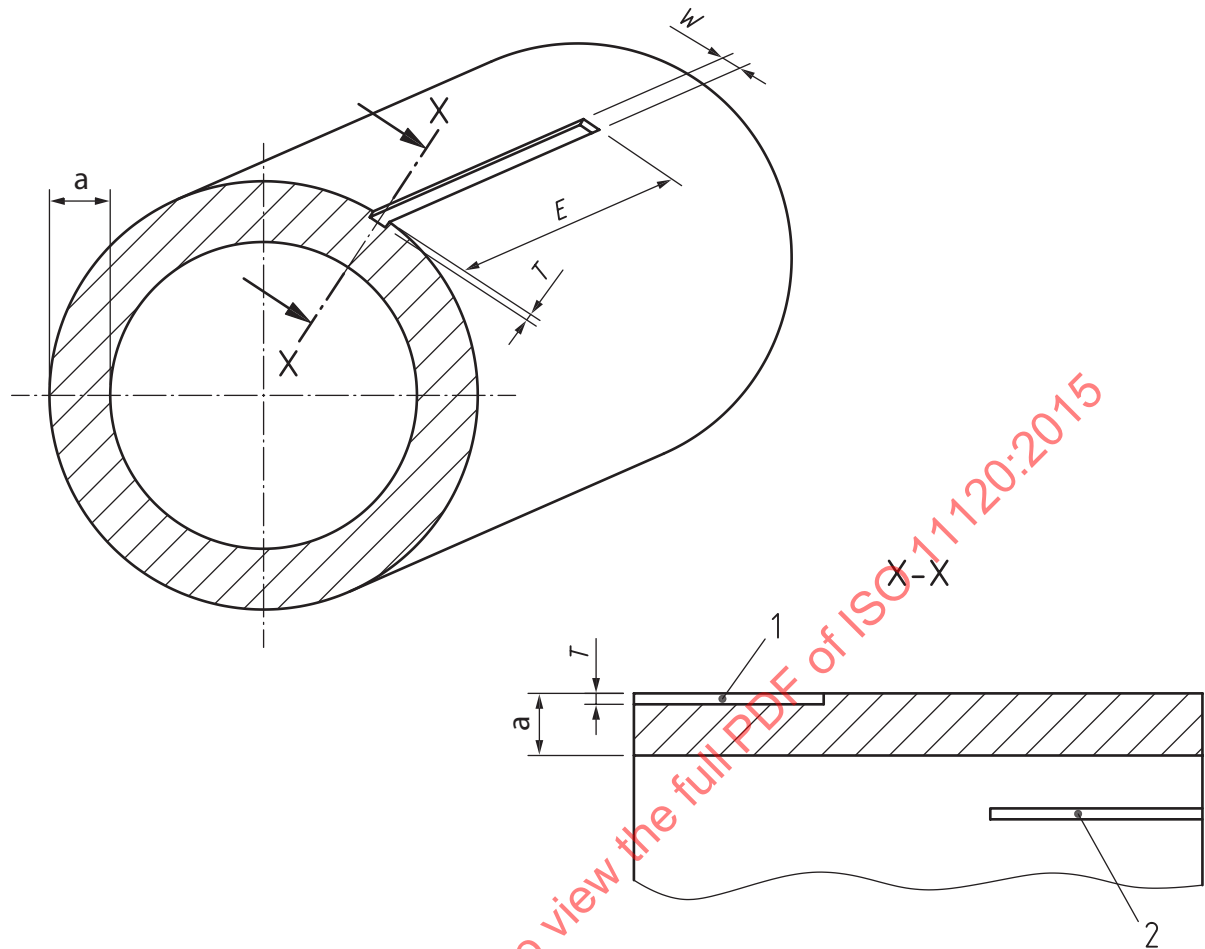
B.5.4 Wall thickness

Any tube which is shown to be below the guaranteed minimum wall thickness shall be rejected.

B.6 Certification

The ultrasonic examination shall be certified by the tube manufacturer.

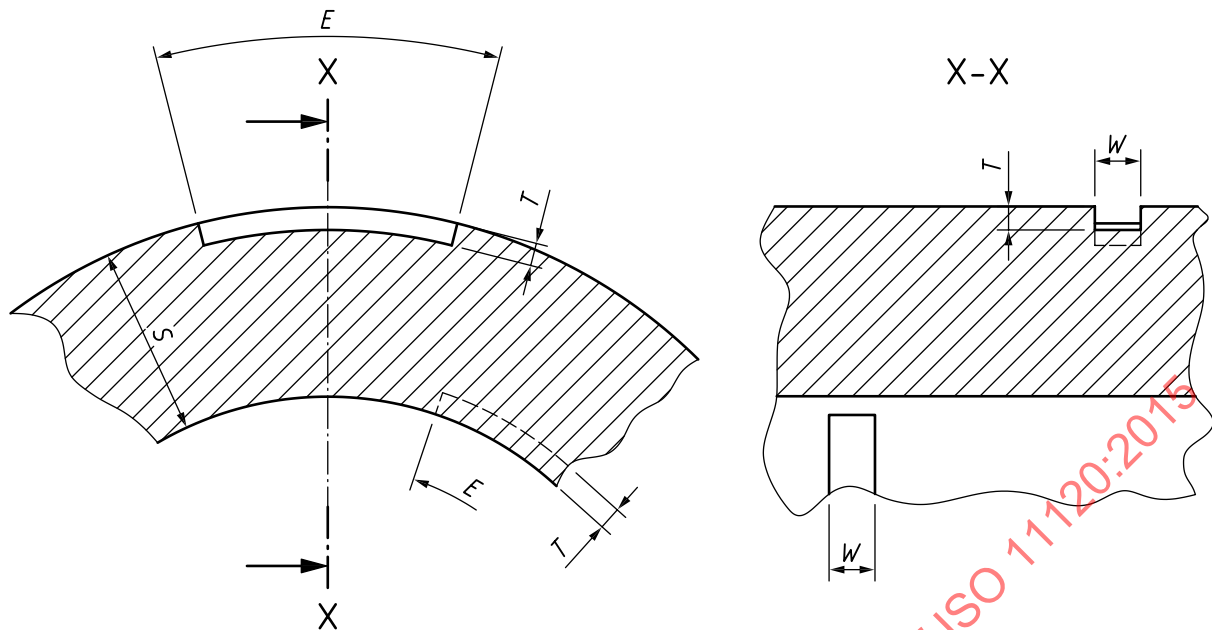
Every tube, which has passed the ultrasonic examination in accordance with this specification, shall be permanently marked with the characters "UT" or with the symbol as shown in [Figure B.4](#) (where the characters "XY" represent the manufacturer's logo or symbol).

**Key**

- 1 outside reference notch
- 2 inside reference notch

$T = (5 \pm 0,75) \% a'$ but $T \leq 1 \text{ mm}$ and $T \geq 0,3 \text{ mm}$; $W \leq 2T$, but if not possible then $W \leq 1 \text{ mm}$, $E \leq 50 \text{ mm}$

Figure B.1 — Design details and dimensions of the reference notches for longitudinal imperfections



NOTE $T = (5 \pm 0,75) \% a'$ but $T \leq 1 \text{ mm}$ and $T \geq 0,3 \text{ mm}$; $W \leq 2T$, but if not possible, then $W \leq 1 \text{ mm}$, $E \leq 50 \text{ mm}$.

Figure B.2 — Schematic representation of the reference notches for circumferential imperfections

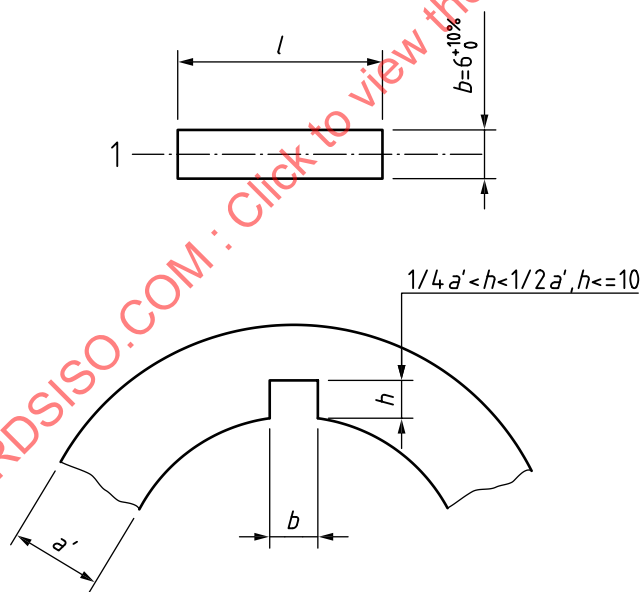


Figure B.3 — Schematic representation of the reference rectangular recess

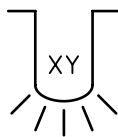


Figure B.4 — UT symbol

Annex C (informative)

Description and evaluation of manufacturing imperfections and conditions for rejection of seamless steel tubes at time of final inspection by the manufacturer

C.1 Introduction

Several types of imperfection can occur during the manufacturing of a seamless steel tube.

Such imperfections can be mechanical or material. They can be due to the basic material used, the manufacturing process, heat treatments, manipulations, necking, machining or marking operations and other circumstances during manufacture.

The aim of this annex is to identify the manufacturing imperfections most commonly met and to provide general guidelines to the Inspector who performs the visual inspection for the Inspection Body. Nevertheless, extensive field experience, good judgement and independence from production are necessary for the Inspector to detect and to be able to evaluate and judge an imperfection at the time of the visual inspection.

C.2 General

C.2.1 It is essential to perform the visual internal and external inspection in good conditions, as follows.

The surface of the metal and in particular of the inner wall should be clean, dry, and suitable enough for proper inspection. Where necessary, the surface shall be cleaned under closely controlled conditions by suitable methods before further inspection.

Appropriate sources of illumination with sufficient intensity shall be used.

After the tubes have been closed and the threads have been cut, the internal neck area shall be examined by means of an introscope, dental mirror or other suitable appliance.

C.2.2 Small imperfections may be removed by local dressing, grinding, machining, or other appropriate method.

Great care shall be taken to avoid introducing new injurious imperfections.

After such a repair, the tubes shall be re-examined and, if the cylindrical wall thickness is reduced, it shall be rechecked.

C.3 Manufacturing imperfections

The most commonly found manufacturing imperfections and their definitions are listed in [Table C.1](#).

Rejection limits for repair or rejection are also included in [Table C.1](#). These rejection limits are established following considerable field experience. They apply to all sizes and types of tube and service conditions. Nevertheless, some customer specifications, some types of tube or some special service conditions can require more stringent criteria.

C.4 Rejected tubes

All rejected tubes shall be rendered unserviceable for their original application.

It may be possible to produce tubes for different service conditions from rejected tubes.

Table C.1 — Manufacturing imperfections

Imperfection	Description	Conditions for rejection and/or actions	Repair or reject
Bulge	Visible swelling of the wall	— All tubes with such a defect	Reject
Dent (flats)	A depression in the wall that has neither penetrated nor removed metal with a depth greater than 1 % of the external tube diameter (see Figure C.1) (see also excessive grinding or machining)	— When the depth of the dent exceeds 2 % ^a of the external diameter of the tube — When the depth of the dent is greater than 1 mm and when the diameter of the dent is less than 30 times its depth ^a	Reject Permit repair
Cut, gouge, metallic or scale impression	An impression in the wall where metal has been removed or redistributed (due basically to the introduction of foreign bodies on the mandrel or matrix during extrusion or drawing operations)	— Inside imperfection: if not superficial, with sharp notches more than 5 % of wall thickness ^b — Outside imperfection: when the depth exceeds 5 % of the wall thickness of the tube	Reject Repair if possible (see C.2.2)
Dent containing cut or gouge	A depression in the wall which contains a cut or gouge (see Figure C.2)	— All tubes with such defects	Reject
Excessive grinding or machining	Local reduction of wall thickness by grinding or machining	— When the wall thickness is reduced to below the minimum design thickness — When it results in the formation of a dent	Reject See “dent” above
Rib	A longitudinal raised surface with sharp corners having a height of 3 % or more than the wall thickness (see Figure C.3)	— Inside imperfection: when height exceeds 5 % of wall thickness or when length exceeds 10 % of the length of the tubes — Outside imperfection: when height exceeds 5 % of wall thickness or when length exceeds 5 times the thickness of the tubes	Repair if possible (see C.2.2)
Groove	A longitudinal notch having a depth of 3 % or more than the wall thickness (see Figure C.4)	— Inside imperfection: when depth exceeds 5 % of wall thickness or when length exceeds 10 % of the length of the tubes — Outside imperfection: when depth exceeds 5 % of wall thickness or when the length exceeds 5 times the thickness of the tubes	Repair if possible or reject (see C.2.2)
Lamination	Layering of the material within the tube wall and sometimes appearing as a discontinuity, crack lap or bulge at the surface (see Figure C.5)	— Inside imperfection: all tubes with such defect — Outside imperfection: all tubes with such defect	Repair if possible or reject Repair if possible or reject (see C.2.2)

^a On small-diameter containers, these general limits may have to be adjusted. Consideration of appearance also plays a part in the evaluation of dents, especially in the case of small tubes.

^b Consideration of appearance and localization (in thicker parts with lower stresses) can be taken into account.

Table C.1 (continued)

Imperfection	Description	Conditions for rejection and/or actions	Repair or reject
Crack	Split, material separation	— When not removable within thickness tolerance — When removable within thickness tolerance	Reject Repair
Neck cracks	Appear as lines which run vertically down the thread and across the thread faces. (They should not be confused with tap marks = thread machining marks.) (see Figure C.6)	— All tubes with such imperfections	Reject
Shoulder folds and/or shoulder cracks	Folding with peaks and troughs situated in the internal shoulder area, which can propagate into the threaded area of the shoulder (see Figure C.7). Cracks can start from folds in the internal shoulder area and propagate into the cylindrical machined or threaded area of the shoulder. (Figure C.8 shows exactly where shoulder cracks start and how they propagate.)	— Folds or cracks that are visible as a line of oxide running into the threaded portion shall be removed by a machining operation until the lines of oxide are no longer visible (see Figure C.7). After machining, the whole area shall be re-inspected carefully and the wall thickness verified.	Repair, if possible
		— If folding or lines of oxide have not been removed by machining, if cracks are always visible or if wall thickness is unsatisfactory	Reject
		— Folds which extend beyond the machined area and are clearly visible as open depressions where no oxides have been trapped into the metal, shall be accepted provided that the peaks are smooth and the root of the depression is rounded	Acceptable
“Orange peel” surface	Orange peel appearance due to discontinuous metal flow	— If sharp cracks are visible in the orange peel surface	Reject
Internal neck threads damaged or out of tolerance	Neck threads damaged, with dents, cuts, burrs or out of tolerance	— When the design permits, threads may be re-tapped and re-checked by the appropriate thread gauge and carefully visually re-examined. The appropriate number of effective threads shall be guaranteed.	Repair
		— If not repairable	Reject
Pitting	Severe surface corrosion	— All tubes with such defects visible after shot blasting	Reject
Non-conformity with design drawing		— All tubes presenting such an imperfection	Repair if possible or reject
Neck ring not secure	Neck ring turns under application of low torque or pulls off under low axial load (see ISO 11117 for guidance)	— All tubes presenting such an imperfection	Repair if possible according to approved method only
^a On small-diameter containers, these general limits may have to be adjusted. Consideration of appearance also plays a part in the evaluation of dents, especially in the case of small tubes. ^b Consideration of appearance and localization (in thicker parts with lower stresses) can be taken into account.			

Table C.1 (continued)

Imperfection	Description	Conditions for rejection and/or actions	Repair or reject
Arc or torch burns	Partial burning of the tube metal, the addition of weld metal or the removal of metal by scarfing or cratering	— All tubes presenting such imperfections	Reject
^a On small-diameter containers, these general limits may have to be adjusted. Consideration of appearance also plays a part in the evaluation of dents, especially in the case of small tubes. ^b Consideration of appearance and localization (in thicker parts with lower stresses) can be taken into account.			

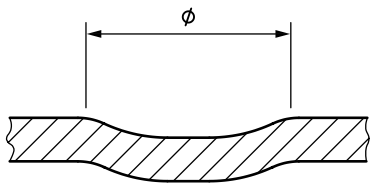


Figure C.1 — Dent

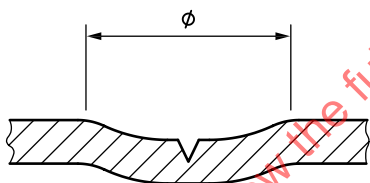


Figure C.2 — Dent containing cut or gouge

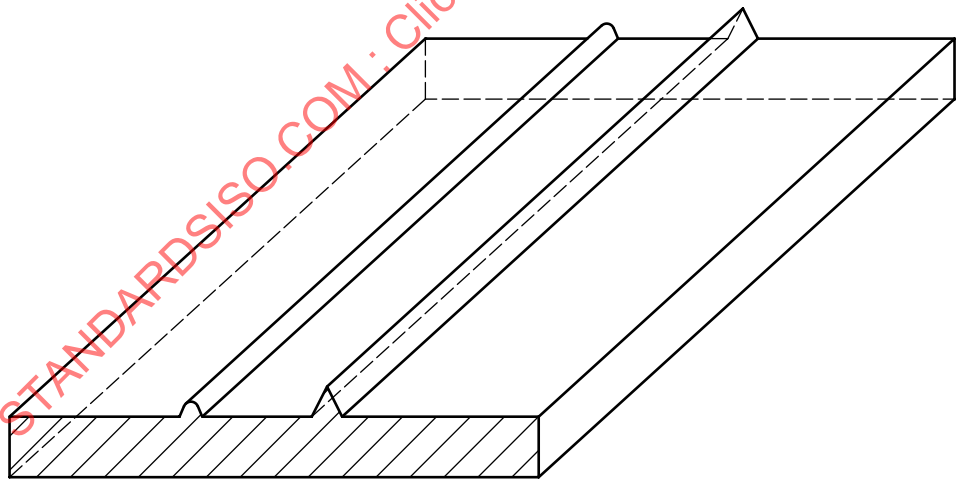


Figure C.3 — Rib